

DRAWINGS ATTACHED

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(54) CONTROL SYSTEM FOR MATERIAL HANDLING
EQUIPMENT

(71) We, INTERNATIONAL HARVESTER COMPANY, of 401 North Michigan Avenue, Chicago, Illinois 60611, United States of America, a Corporation constituted under the laws of the State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a control system comprising at least two hydraulic motors. More specifically the invention relates to control systems for a material handling mechanism mounted upon a vehicle.

Material handling apparatus of the prior art, for example a front end loader or a backhoe, generally have one or more mechanical linkages interconnecting a material handling bucket or shovel with a vehicle, each linkage being controlled by a separate hydraulic motor, and a separate directional flow control valve which in turn is controlled by a separate control lever. For example, backhoes in production today utilize a separate lever controlling each flow control valve which separately actuates its boom, rotary actuator, dipper stick and bucket. Thus four separate levers are utilized to perform digging operations for the current backhoes, and excellent dexterity is required on the part of the operator economically to utilize such devices. Similarly, the prior art backhoes utilize purely mechanical linkages for controlling directional flow control valves which actuate the rotary actuator, boom, dipper stick and bucket.

According to the present invention there is provided a control system comprising at least two hydraulic motors, a source of fluid pressure, at least two pressure oper-

ated directional flow control valves each inter-connected between the source of fluid pressure and a respective hydraulic motor for controlling flow of hydraulic fluid to and from the motor, a control device capable of movement in at least two senses, and electrical means interconnected between the control device and each directional flow control valve for actuating each control valve in response to movement of the control device in a respective one of the senses; the said electrical means serving to convert electrical signals representing the movement of the control device into fluid pressure signals for controlling the directional flow control valves.

The present invention further includes a vehicle including material handling equipment, for example an earth-working tool, comprising at least two linkages operable by a control system in accordance with the immediately preceding paragraph.

In accordance with a preferred embodiment of the present invention there is provided a vehicle including a backhoe comprising a boom rotatable about vertical and horizontal axes, a dipper stick mounted on the boom and rotatable about a horizontal axis, and a bucket mounted on the dipper stick and rotatable about a horizontal axis, hydraulic motors associated with each element of the backhoe, i.e. the boom, dipper stick and bucket, for moving the associated elements about their respective axes, a control movable in four senses, the movement in each sense simulating the movement of a respective element of the backhoe about one of the said axes, a source of fluid pressure, pressure operated directional flow control valves each interposed between the source of fluid pressure and a respective hydraulic motor for controlling flow of hydraulic fluid to and from each motor, and electrical means interconnected bet-

ween the control lever and each directional flow control valve for actuating each control valve in response to movement of the control lever in a respective one of the senses; the said electrical means serving to convert electrical signals representing the movement of the control lever into fluid pressure signals for controlling the directional flow control valves.

Preferably the movements of the control device in each of the senses are analogous to the movements of the respective linkages of the earth-working tool.

In order that the invention may be better understood, preferred embodiments thereof will now be described, by way of example only, and with reference to the accompanying drawings, in which:—

Figure 1 is a perspective view of the rear portion of a first embodiment of a vehicle in accordance with the present invention and having mounted thereon a conventional backhoe;

Figure 2 is a rear elevational view of the pressure operated directional flow valves which are utilized to direct flow to and from the hydraulic motors actuating the various linkages of the backhoe of the vehicle of figure 1,

Figure 3 is an exploded perspective view of a single handle control device utilized to actuate the directional flow control valves which in turn direct fluid to and from the hydraulic motors of the vehicle of figure 1.

Figure 4 is a side elevational view of the rotary actuator of the backhoe of the vehicle of figure 1 having its boom attached thereto, with a schematic view of the electro-hydraulic control system utilized in controlling the boom of the backhoe;

Figure 5 is a diagram of the electrohydraulic circuit of figure 4.

Figure 6 is a side elevational view of a rotary actuator and boom of a backhoe of a second embodiment of a vehicle in accordance with the present invention with a schematic view of an electro-hydraulic control system which actuates the rotary actuator and in turn controls the rotational movement of the backhoe boom;

Figure 7 is a diagram of the electrohydraulic control system of figure 6;

Figure 8 is a top view illustrating the rotary actuation of the backhoe of figure 6 and its correlated movement of the control device;

Figure 9 is a perspective view of a mounting element for the control device of figure 8;

Figure 10 is a schematic view of an additional control circuit which may be incorporated into either of the embodiments of the invention illustrated in the drawings.

In the attached drawings, a tractor 10 is

provided with an operator's station 13 having thereon a seat 11 adjacent to which is a control device consisting of a single-handle control lever 35 operative to control all of the movements of the associated material-handling apparatus. The material-handling apparatus comprises a backhoe having a support stand 12 suitably attached to the tractor by conventional means and being further supported upon the ground surface by stabilizer arms 14 (only one of which is here shown), the stabilizer itself being controlled by hydraulic motor 15. Appropriate brackets 16, 16 extending rearwardly from support stand 12 carry a rotary hydraulic motor 30 constrained from rotation by suitable means and having a shaft 31 extending therethrough for rotatably driving the swing mount 17 as fluid energy is directed to the actuator 30. The swing mount 17 in turn rotatably mounts a boom 18, dipper stick 19 and bucket 20, these linkages and the bucket being controlled in their movement by hydraulic rams 21, 22, and 23 respectively.

Disposed underneath the operator's station 13 for conveniently controlling the movement of the rams 15, the rotary actuator 30, and the hydraulic rams 21, 22 and 23, is a valve bank 62 comprising six directional flow control valves 61. Upon one end of this valve bank is mounted a conventional end cap 63 to which is connected an intake conduit 67 for delivering fluid from a pump to the valves. Adjacent the opposite end of the valve bank 62 is another identical end cap 63 to which is connected a conduit 79 for returning hydraulic fluid to the reservoir. These valves 61 are substantially similar to that disclosed in U.S. patent No. 2,873,762. Further reference may be had to a cross sectional view of these same valves in figures 4 and 6 for a clearer understanding thereof.

Reference may now be had to figures 4 and 5 in which one of the control valves 61 is integrated into the control circuit of the present invention for the hydraulic motor 21 which effectuates movement of the boom 18 of the backhoe. (As later explained, such a circuit is associated with each element of the backhoe).

A pump P delivers fluid from reservoir S to directional control valve 61 through a conduit 67. As shown in figure 2 such fluid would normally be delivered to an end cap 63 of valve bank 62, such being omitted from figure 4 for purposes of simplicity. This fluid is then directed into an open center passage 68 and normally flows directly out of this valve and into the opposite end cap and back to sump. As more fully disclosed in U.S. patent No.

2,873, 762, a spool 70 is reciprocable within the valve 61 whereby the reduced diameters of said spool in conjunction with various lands and parting will control the direction of fluid flow to and from the hydraulic motor 21. Briefly setting out such structural and functional characteristics of this well known valve, it will be observed that if spool 70 is shifted either to the right or to the left, fluid can no longer flow through the open or low pressure passage 68 since the normal diameter of the spool precludes such, and fluid is then directed into a high pressure passage 69 for delivery to the hydraulic motor 21 via one of the motor ports 72 or 73. Thus, assuming the spool is shifted to the right, the low pressure, open center feature of the valve is closed by a normal diameter of the spool, and hydraulic fluid is then urged into the high pressure passage 69, across the reduced diameter of the spool at 81 and out port 72 to contact the hydraulic ram 21. Fluid is then returned from the opposite end of the ram 21 via conduit 77, motor port 73, across reduced diameter 83 of the spool and out of exhaust port 78 to the sump S through a conduit 79. Reciprocation of the spool in the opposite direction merely reverses the direction of flow above explained. These passages and portings of the open center valve being quite conventional, no further explanation is deemed necessary other than reference to the above identified patent.

Movement of the spool 70 of the valve 61 is controlled by expansionable chamber device or servo motor 85 and includes a housing 86 connected to the valve 61 and having a piston element 87 attached to the spool 70 whereby any unbalance of fluid energy delivered through a port 88 or a port 89 is effective to cause reciprocation of the piston 87 and the spool 70 to control the direction of fluid flow to hydraulic motor 21. Fluid is supplied to the servo motor 85 from a pump P1 delivering fluid through a conduit 113 to solenoid operated valves 110 and 111. These solenoid valves may appropriately be a conventional "normally open" three-way valve in which the fluid is normally directed through the valve to the ports 88 and 89 of servo motor 85 but upon selective actuation they will dump both supply fluid and fluid on the appropriate side of piston 87 to sump S whereby the normal pressure on the opposing side of the piston will cause the spool to reciprocate. Another preferable solenoid valve would include the "four-way normally open—normally open solenoid valve, Type V955" made and sold by Skinner Precision Industries, Inc. of New Britain, Connecticut. This valve is basically a combination of two three-way valves dis-

closed above, but incorporated into one housing.

For controlling actuation of the solenoid valve 110 or 111 and consequent actuation of spool 70, a bridge circuit is interposed between a control member or lever 35 and spool 70 of the control valve 61. As more clearly depicted in Figure 5, a bridge circuit is established in which two potentiometers 44 and 92 are connected in parallel and a voltage impressed across them. The wiper of potentiometer 44 is rotatably attached to the control lever 35 as hereinafter explained, and the wiper of potentiometer 92 is rotatably attached by assembly 91 (see Fig. 2) to the spool 70 of control valve 61.

The wiper leads are then connected to a null detector means or comparator means 109 which will detect any unbalance or voltage differential in the bridge circuit and amplify a signal created by said unbalance to actuate the appropriate solenoid valve 110 and 111. Thus, upon varying the resistance in potentiometer 44, the comparator means 109 will actuate solenoid valve 110 or 111 so as to dump fluid from the appropriate chamber on one side of piston 87 and normal pressure on the opposite side will effectuate reciprocation of spool 70, the spool movement rotating the wiper of potentiometer 92 such that the bridge circuit will again be balanced. Thus, it should be appreciated that movement of a control lever 35 about a horizontal axis will produce a corresponding proportional movement of spool 70. With reference to the components of the electro-hydraulic control system, it is to be noted that the null detector or comparator means 109 is a conventional item and readily obtainable in the market in various forms. an example of other forms of the electrical circuits which may provide excellent alternatives would include a series connection of two variable resistances in parallel with a series connection of two fixed resistances, the comparator 109 being inter-connected between the resistances of each parallel branch. The pump delivering fluid to the solenoid valves is preferably a low volume and low pressure pump, but may be the same pump utilized to deliver fluid to the backhoe itself if acceptable flow rates are provided. The solenoid valves selected for the system should preferably have a small flow rate for the intended pump and pressure since more accurate movement of the spool 70 may be obtained. It should be appreciated that solenoid members acting directly upon the spool could be utilized as well as other systems including conventional electro-hydraulic servo valves should the potentiometer reading be taken from the valve

in such a manner as to be proportional to the flow rate through such valve.

Referring back to Figure 4, the potentiometer 92 is attached to the spool 70 in a simple mechanical manner. For example, a bracket 93 is fixedly attached to the console 13 of the backhoe apparatus with the potentiometer secured therein and constrained against rotation. A link 94 is then constrained for rotation with the wiper of the potentiometer 92, reciprocation of the spool causing rotation of this link through a pivotal element 95 so as to vary the impedance of this branch of the bridge circuit.

Each of the directional flow control valves 61 associated with the rotary actuator, and the hydraulic motors 21, 22 and 23 may be conveniently provided with such an electrical control circuit.

For manipulating the command potentiometer 44 as well as a command potentiometer for each control circuit associated with motors 30, 21, 22 and 23, applicants have provided a unique control device which is movable in a plurality of different senses whereby movement of the control device produces a similar directional movement of a respective element of the material handling mechanism. As shown in Figure 3, this control means 35 comprises a vertical support 36 which may be appropriately journaled in a housing 57 in a manner permitting rotational movement thereof. Attached to the lower end of this vertical support 36 is a gear 38 which, upon rotation, will drive a pinion 39 constrained for rotation with the stem of a potentiometer 40, the latter being fixedly supported in housing 57. Thus, as the lever 35 is rotated about a vertical axis, a varying resistance in a potentiometer 40 is incurred and, since this variable command impedance forms one branch of a bridge circuit which is part of an electro-hydraulic circuit associated with a valve 61 controlling flow to actuator 30 and otherwise identical to that disclosed in Figures 4 and 5, the rotational movement of lever 35 about a vertical axis will control rotational movement of the shaft 31 of rotary actuator 30.

In order to control command impedance 44 and boom 18 and motor 21, as previously explained in Figures 4 and 5, a yoke 37 is provided on the upper end of vertical support 36, and common apertures 45 connect same to another yoke member 41 as well as to an extensible arm 46, the latter connection being made rigid by pin connections extending the adjacent diagonal apertures (unnumbered). The yoke 41 then extends downwardly from the pivotal connection 53 with the extending arm carrying the potentiometer 44 constrained for

movement therewith. The stem of the potentiometer 44 carries a pinion 43 which is driven by a rack 42 mounted on yoke 37, and thus as the extensible arm 46 is rotated about a horizontal axis passing through a pivotal connection 53, the stem of the potentiometer 44 is rotated so as to obtain a variable impedance or resistance. This potentiometer 44 appropriately controls movement of the boom 18 as previously discussed in relation to figures 4 and 5 by connecting same with another bridge circuit element attached to the spool of the directional flow control valve 61 associated with hydraulic motor 21.

The extensible arm 46 may additionally consist of an outer extensible member 47 and an inner member 48 over which the outer member is telescoped. A potentiometer 49 is then fixed by a bracket 50 upon said outer member, and upon extension and retraction of outer member 47, a rack 52 and a gear 51 constrained for rotation with the stem of potentiometer 49 creates a variable impedance in said potentiometer. Appropriately, this potentiometer may be integrated in a bridge circuit with a potentiometer associated with the flow control valve 61 which is connected to hydraulic motor 22 effectuating movement of the dipper stick 19.

Finally a handle 54 is rotatably secured upon the end of extensible member 47, and a bolt member 55 constrained for rotation by any conventional means with handle 54 extends through the handle and is joined to the stem of potentiometer 56 secured to member 47. Again, rotation of the control handle 54 will vary the impedance of potentiometer 56, and if this potentiometer is integrated into the electro-hydraulic circuit of figures 4 and 5 which is further associated with motor 23, rolling movement of control handle 54 will cause rolling of the bucket 20.

The control device shown above can therefore be moved in a number of senses, i.e. by rotation of the vertical support 36 about a vertical axis, by rotation of the extensible arm 46 about a horizontal axis, by axial extension of the extensible arm 46 and by rotation of the handle 54 about its horizontal axis. Furthermore, it should be appreciated that, as constructed, the control means 35 permits motions analogous to those of the linkages of the backhoe itself. For example if the operator desires to rotate the backhoe, he merely rotates control lever 35 about its vertical axis causing an unbalance in the bridge circuit of the associated potentiometers and fluid may be directed to the hydraulic actuator 30 to rotate the backhoe. Similarly rotational motion of the extensible arm 46 about a horizontal axis passing through the

pivotal connection 53 causes actuation of the hydraulic valve controlling the boom and such movement is somewhat analogous to movement of the control means. Similarly extension and retraction of hydraulic ram of extensible member 47 will operate the directional flow control valve associated with hydraulic motor 22 to extend and retract the dipper stick 19 in an analogous fashion, and finally rotational movement of member 54 will cause similar rotational movement of bucket 20. This analogous and corresponding movement directional of the control member and the backhoe is a most significant advantage since such is effective to reduce cycle time of the handling operation as well as enabling an operator with little experience to rapidly master the techniques of such a machine. Thus it should be appreciated that by utilization of a control system as disclosed in figures 4 and 5 with a single control lever 35 and applying same to each of the control valves 61 located within valve bank 62, significant advantages may be obtained.

Figures 6 and 7 disclose an additional embodiment of the present invention in which the directional control valve movement not only corresponds to movement of the control means 35, but the hydraulic motor and associated linkage itself will accurately correspond to movement of control means 35 whereby a position control system may be obtained. In this embodiment, a bracket 132 is disposed upon flange 16 and extends above the rotational shaft 31 of rotary actuator 30, and has mounted thereon a potentiometer 131 whose stem is constrained for rotation with the shaft 31 of the motor 30. As schematically disclosed in Figure 7, this potentiometer 131 is placed in parallel with the potentiometer 40 but stem rotation is such that a positive increasing voltage of potentiometer 40 will result in a decreasing voltage in potentiometer 131 upon rotation of actuator 30. Thus, the comparator 109 compares the voltage difference between potentiometer 92 and potentiometers 40 and 130. Accordingly, if the control lever 35 is rotated to the right, the wiper of the potentiometer 40 will be moved downwardly as shown in Figure 7, and the comparator will detect an unbalance and actuate solenoid valve 111 to permit spool 70 to be moved downwardly. This downward movement will deflect the stem of potentiometer 92 as shown by dotted lines and simultaneously fluid will be directed to the rotary actuator so as to rotate same in a clockwise direction. This clockwise movement of the rotary actuator in turn controls the wiper of potentiometer 130 to reduce its impedance as the actuator ap-

proaches the corresponding position of control lever 35. Thus, the total resistance seen by the comparator on one side of the bridge circuit diminishes upon rotation of the actuator and the null detector will then gradually actuate solenoid valve 110 to return the spool to neutral such that potentiometer 92 is again in balance with potentiometers 40 and 130 in parallel. As disclosed in Figure 8, an angular movement alpha of control arm 35 will thus result in a corresponding angular movement alpha of the boom 18 and a position control system is effectuated.

As more fully pointed out in figure 9, a tubular member 57 may be mounted upon the console 13 to rotatably support control lever 35, apertures 58 being provided in the upper end surface of member 57. Appropriately, dowel pins 59 may be inserted into these apertures to limit the rotational movement of control means 35 about a vertical axis. Consequently, if the position control system of figures 6 and 7 is utilized to control swing movement of the backhoe, a position controlled system may additionally yield a return to dig system. For example, if dowel pins are placed in the end surface of tubular member 57 corresponding to a position of the proposed trench and corresponding to a position for bucket dump, the outer limits of rotational movement of the backhoe will be fixed and by merely rotating the lever 35 between these limits, the rotary motor 30 will always return the boom to these limits. Under such circumstances the dowel pin may reflect a return to dig position and the operator need not concern himself with accurate positioning of the bucket in a trench.

Figure 10 discloses a circuit for controlling hydraulic motors 15 which position the stabilizer arms 14, and support the boom structure during the digging operation. This circuit may be used to control the stabilizer range of either of the embodiments of the present invention. Since continuous movement is not desired, the two end valves of bank 62 are not provided with potentiometers, and the solenoid valves are operated by on-off switches, 120 and 121. As opposed to the bridge arrangement previously discussed the remainder of the system, e.g. valve 61, solenoids, and chamber device 85 remain the same.

The embodiments of the invention described above with reference to the accompanying drawings provide a most advantageous electrical hydraulic system for controlling movement of associated hydraulic motors by electrically controlling actuation of a flow control valve. A single control device capable of distinct movements in

several senses controls several directional flow control valves and their associated hydraulic motors. This control device is simple to operate and does not require much manual dexterity on the part of the operator. Further, the movements of the control device are correlated with the anticipated movement of the elements to be controlled. In this way, follow-up system is effected in which a command signal is followed by a correlated movement of the associated motor controlled element. In addition to this follow-up system, provision has been made in the second embodiment described for position control system. Finally, by incorporating the solenoid actuated valve which is effective to control movement of the flow control valve, accurate metering of fluid through the flow control valve may be effected and infinite and incremental movements of the associated hydraulic motors and linkages may result therefrom.

It should be readily appreciated that the system herein disclosed may be employed with numerous vehicles so as to control many material-handling operations by a single lever. Even in the utilization of continuously rotating hydraulic motors, the herein disclosed control system may be effective to accurately control said motor so as to afford braking and incremental movement, such not being heretofore attainable.

WHAT WE CLAIM IS:

1. A control system comprising at least two hydraulic motors, a source of fluid pressure, at least two pressure operated directional flow control valves each interconnected between the source of fluid pressure and a respective hydraulic motor for controlling flow of hydraulic fluid to and from the motor, a control device capable of movement in at least two senses and electrical means interconnected between the control device and each directional flow control valve for actuating each control valve in response to movement of the control device in a respective one of the senses; the said electrical means serving to convert electrical signals representing the movement of the control device into fluid pressure signals for controlling the directional flow control valves.

2. A control system according to claim 1 wherein the electrical means is effective to compare the displacement of the control device in each sense with the setting of the respective directional flow control valve, and to actuate the directional flow control valves in response to the comparison.

3. A control system according to claim 1 or claim 2, wherein the electrical means includes an electrical bridge circuit having

a first variable impedance branch which is variable by movement of the control device in one of the senses whereby an imbalance in the bridge circuit may be produced, a second variable impedance branch variable by the directional flow control valve associated with the movement of the control device in the said sense, and comparator means connected to the output of the bridge circuit for detecting an imbalance in the bridge circuit, and means is provided for controlling the directional flow control valve in response to the comparator means so that the imbalance in the bridge circuit is removed.

4. A control system according to claim 3, wherein the directional flow control valve includes a reciprocable spool and the first impedance branch includes a potentiometer the resistance of which is varied by movement of the control device in the said sense, and the second impedance branch includes a potentiometer the resistance of which is varied by reciprocation of the spool.

5. A control system according to claim 4, wherein expansible chamber means is provided for effecting reciprocation of the spool and electrically operable hydraulic means is provided for directing hydraulic fluid to the expansible chamber means.

6. A vehicle including material handling equipment comprising at least two linkages each operable by a respective hydraulic motor, and a control system in accordance with any one of the preceding claims.

7. A vehicle according to claim 6, wherein the movements of the control device in each of the senses are analogous to the movements of the respective linkages of the material handling equipment.

8. A vehicle according to claim 6 or claim 7 as appendent to claim 3, wherein the bridge circuit controlling one of the linkages includes an additional variable impedance branch the impedance of which is varied by movement of the linkage so that the position of the control device with respect to one of the senses corresponds to the position of the said one linkage.

9. A vehicle including a backhoe comprising a boom rotatable about vertical and horizontal axes, a dipper stick mounted on the boom and rotatable about a horizontal axis, and a bucket mounted on the dipper stick and rotatable about a horizontal axis, hydraulic motors associated with each element of the backhoe, i.e. the boom, dipper stick and bucket, for moving the associated elements about their respective axes, a control lever movable in four senses, the movement in each sense simulating the movement of a respective element of the backhoe about one of the said axes, a source of fluid pressure, pressure operated directional flow control

- valves each interposed between the source of fluid pressure and a respective hydraulic motor for controlling flow of hydraulic fluid to and from each motor, and electrical means interconnected between the control lever and each directional flow control valve for actuating each control valve in response to movement of the control lever in a respective one of the senses; the said electrical means serving to convert electrical signals representing the movement of the control lever into fluid pressure signals for controlling the directional flow control valves.
- 10 10. A vehicle substantially as hereinbefore described with reference to Figures 1, 2, 3, 4, 5 and 10 and Figures 6, 7, 8, 9 and 10 of the accompanying drawings.

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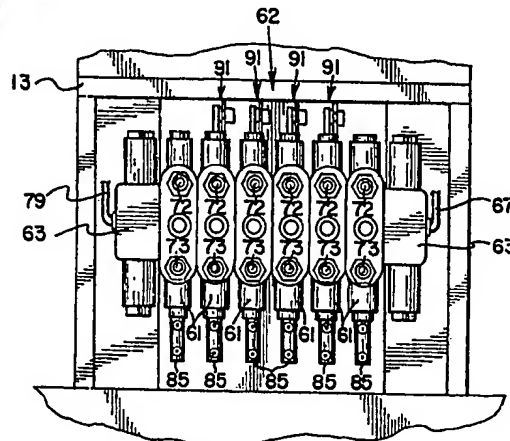
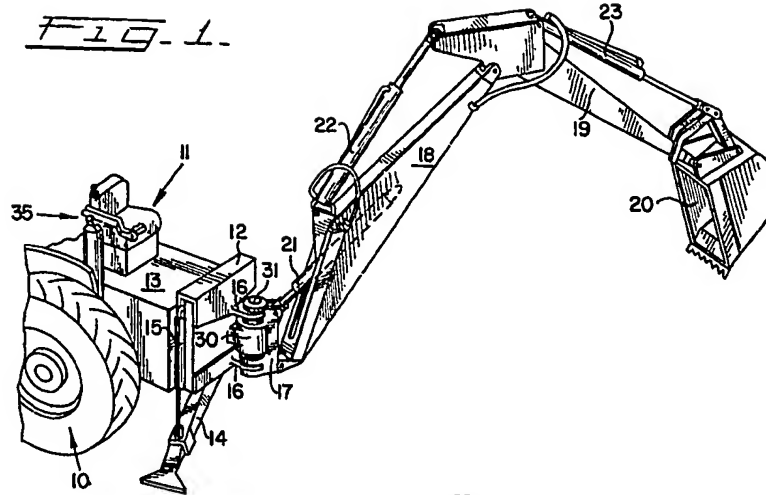
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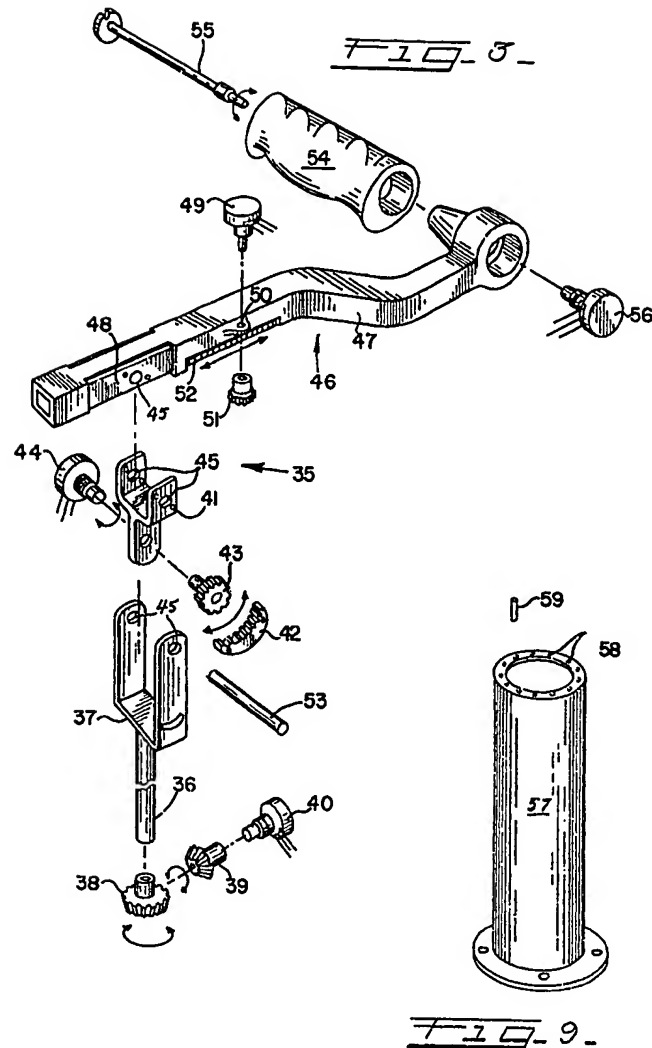
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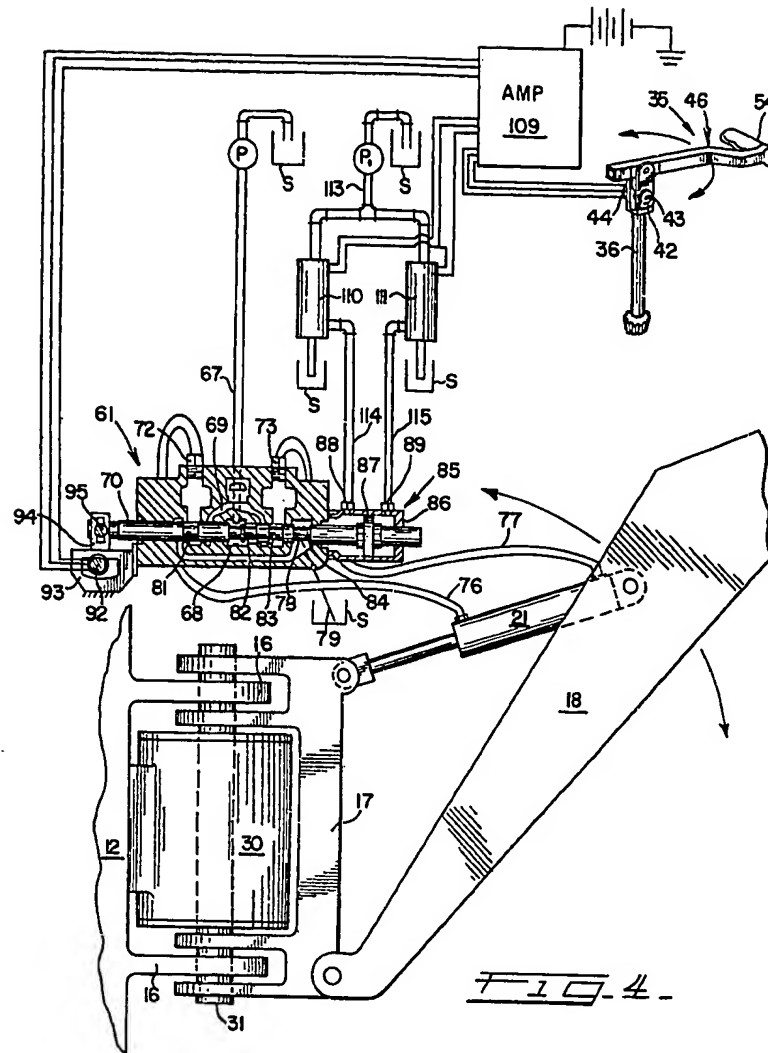
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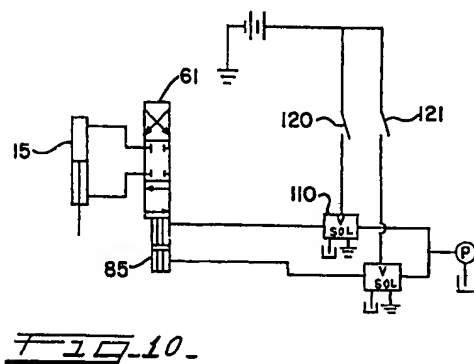
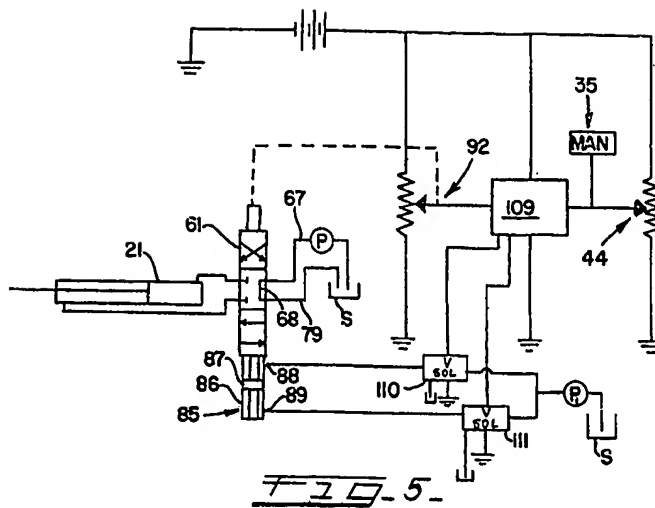
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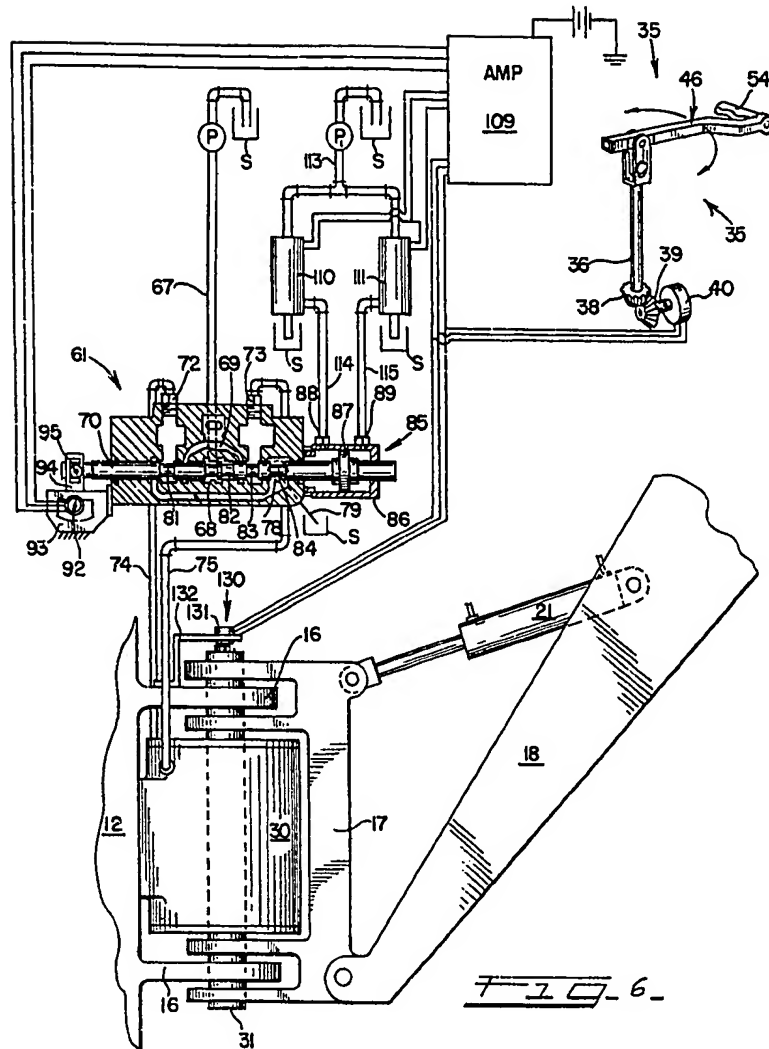
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Fig. 1.Fig. 2.









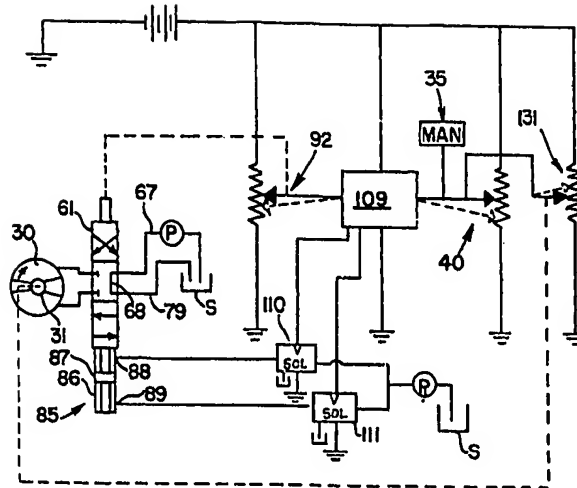


FIG. 7.

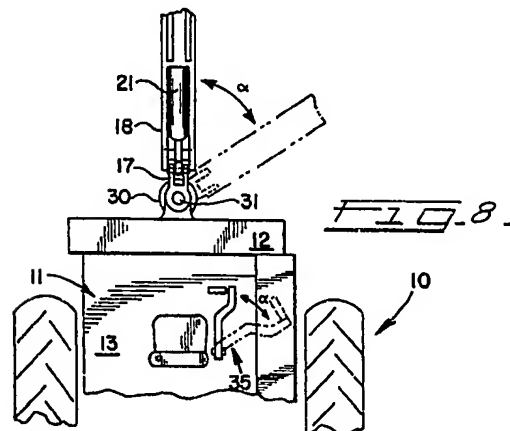


FIG. 8.